EE 362 — [redacted] Quiz 1

Q A unity feedback system has the following forward transfer function:

$$G(s) = \frac{10(s+20)(s+30)}{s(s+25)(s+35)}$$

Find the steady state error for the following inputs

1) $15\,u(t)$ 2) $15t\,u(t)$ 3) $15t^2\,u(t)$

For 1) [redacted] $e_{(\infty)}^{\text{step}} = \lim_{s\to 0} s\,\frac{R(s)}{G(s)+1} = \lim_{s\to 0} \frac{s \cdot \frac{15}{s}}{G(s)+1} = \boxed{\neq 0}$

For 2) $e_{(\infty)}^{\text{ramp}} = \lim_{s\to 0} \frac{s \cdot \frac{15}{s^2}}{G(s)} = \lim_{s\to 0} \frac{15}{s \cdot \frac{10(s+20)(s+30)}{s(s+25)(s+35)}} = \boxed{8.187}$

For 3) $e_{\text{parabolic}}^{(\infty)} = \lim_{s\to 0} \frac{s \cdot \frac{15}{s^3}}{G(s)} = \lim_{s\to 0} \frac{15}{s^2 \cdot \frac{10(s+20)(s+30)}{s(s+25)(s+35)}} = \boxed{\infty}$

Q An input of $25t^3\,u(t)$ is applied to the input of a type 3 unity feedback system as shown where :-

$$G(s) = \frac{210(s+4)(s+6)(s+11)(s+13)}{s^3(s+7)(s+14)(s+19)}$$

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$$E(s) = \frac{R(s)}{1+G(s)} = \frac{\frac{150}{s^4}}{1 + \frac{210(s+4)(s+6)(s+11)(s+13)}{s^3(s+7)(s+14)(s+19)}}$$

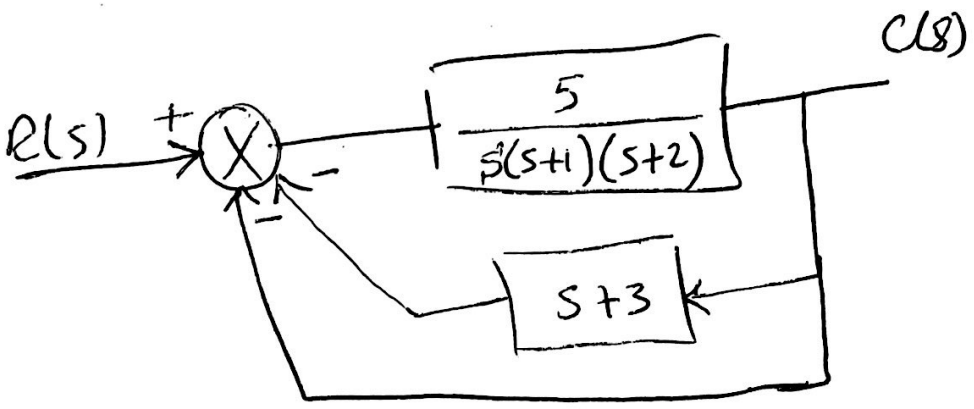
$$e(\infty) = \lim_{s\to 0} sE(s) = \frac{150}{\frac{210(4)(6)(11)(13)}{(7)(14)(19)}} = 0.387$$

Q For the system shown below

(a) Find K_p, K_v, and K_a

(b) Find the steady state error for an input of $50u(t)$ and $50t^2u(t)$

(c) state the system type



$$G_2(s) = \frac{\frac{5}{s(s+1)(s+2)}}{1 + \frac{5(s+3)}{s(s+1)(s+2)}} = \frac{5}{s(s+1)(s+2)+5(s+3)} = \frac{5}{s^3+3s^2+7s+1}$$

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$$K_p = \lim_{s\to 0} G_e(s) = \frac{\frac{1}{5}}{1+\frac{5}{3}} = \frac{1}{3}$$

$$K_v = \lim_{s\to 0} sG_e(s) = 0$$

$$K_a = \lim_{s\to 0} s^2 G_e(s) = 0$$

(b) For $50u(t) \Longrightarrow e(\infty) = \frac{50}{1+K_p} = 37.5$

For $50tu(t) \Longrightarrow e(\infty) = \infty$

For $50t^2u(t) \Longrightarrow e(\infty) = \infty$

(c) Type 0

Q Given the unity feedback system shown below

$$G(s) = \frac{100500(s+5)(s+14)(s+23)}{s(s+27)(s+\alpha)(s+33)}$$

Find the value of α to yield $K_v = 25000$

$$K_v = \lim_{s\to 0} sG(s) = \frac{100500(5)(14)(23)}{(27)(\alpha)(33)} = 25000$$

$$\boxed{\alpha = 7.26}$$

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Q For the unity feedback system, where

$$G(s) = \frac{K(s+13)(s+19)}{s(s+6)(s+9)(s+22)}$$

find the value of K to yield a steady state error of 0.4 for a ramp input of $2.7t\,u(t)$

$$e_{ss} = \frac{2.7}{K_v} = 0.4$$

$$K_v = \lim_{s \to 0} sG(s) = \frac{K(13)(19)}{(6)(9)(22)}$$

$$0.4 = \frac{2.7}{\frac{K(13)(19)}{(6)(9)(22)}} \Longrightarrow \boxed{K = 325}$$

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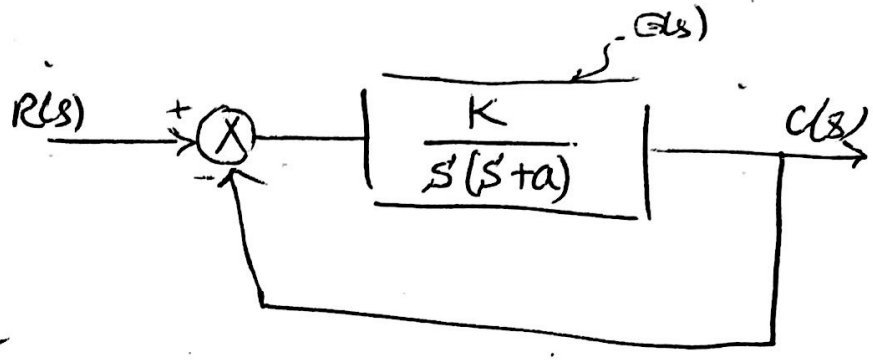
For the system shown below find the sensitivity of steady state error to changes in parameter "K" and parameter "a" with ramp inputs



Solution :-

$$e(\infty) = \frac{1}{K_v} = \frac{a}{K} \quad \text{from } K_v = \lim_{s \to 0} sG(s)$$

$$= \lim_{s \to 0} s \frac{K}{s(s+a)} = \frac{K}{a}$$

The sensitivity of $e(\infty)$ to changes in parameter "a" is

$$S_{ea} = \frac{a}{e} \frac{\partial e}{\partial a} = \frac{a}{\frac{a}{K}} \left[\frac{1}{K}\right] = 1$$

The sensitivity of $e(\infty)$ to changes in parameter "K" is

$$S_{ek} = \frac{K}{e} \frac{\partial e}{\partial K} = \frac{K}{\frac{a}{K}} \left[\frac{-a}{K^2}\right] = -1$$

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MAR 428

Test II

* Steady state error

* Sensitivity

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ج نظام التحكم (system type) :

هو أقل أس موجود في المقام أو هو أس العامل المشترك الأكبر.

$$G(s) = \frac{2}{s^2 + 3s + 1}$$ type 0

$$G(s) = \frac{50}{s^2(s+1)(s+2)} = \frac{50}{s^4 + 3s^3 + 2s^2}$$ type 2

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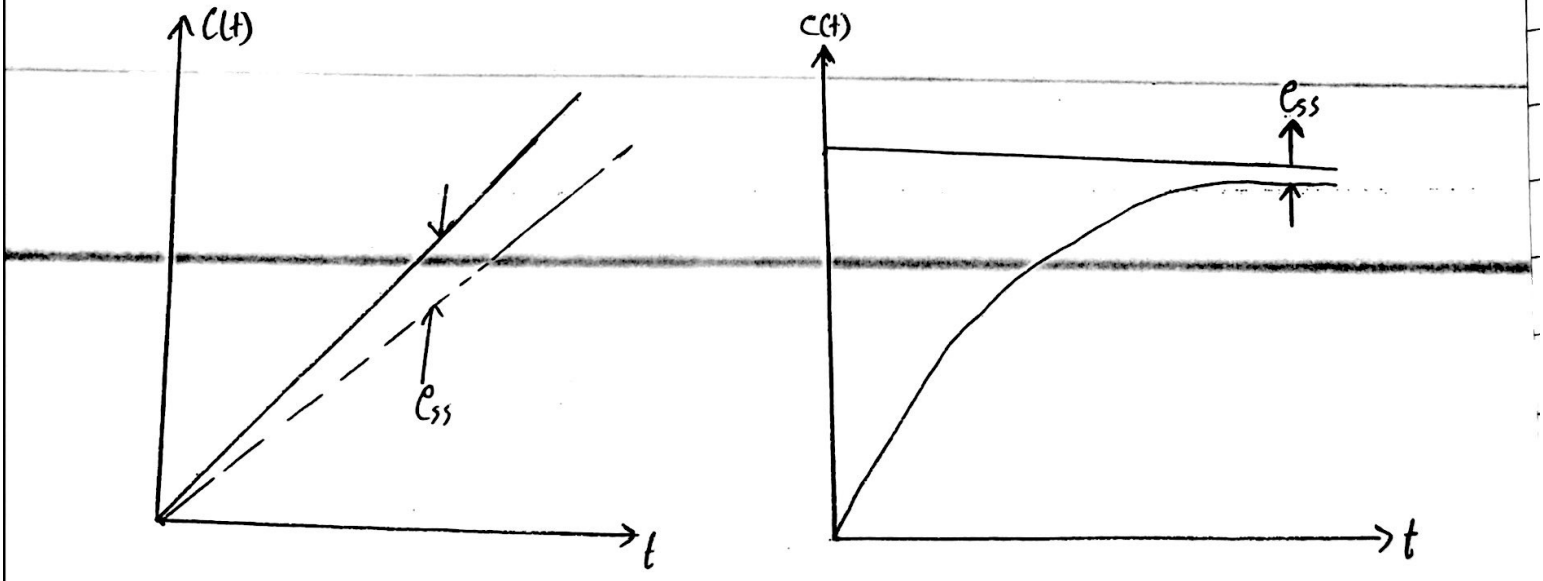
* تعريف الخطأ حالة الاستقرار :

هو عدم مقدرة إشارة خرج النظام على المطابقة مع الإشارة المرجعية بالدقة المطلوبة،

أي هو الفرق بين إشارة الدخل وقيمة إشارة التغذية العكسية



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* حساب الخطأ بدلالة دالة التحويل الشاملة :

$$e_{ss} = \lim_{s \to 0} s \frac{R(s)}{} [1 - T(s)]$$

حيث R(s) تمثل دالة الدخل او اشارة الدخل ويمكن ان تكون :

Step input	Ramp input	Parabolic input
$r(t) = u(t)$	$r(t) = \frac{1}{t}$	$r(t) = 1/t^2$
$R(s) = \frac{1}{s}$	$R(s) = \frac{1}{s^2}$	$R(s) = 1/s^3$

مثال : أوجد الخطأ للمنظومة إذا علمت أن دالة التحويل الشاملة

$$T(s) = \frac{10}{s^2 + 7s + 10}$$

واشارة الدخل هي اشارة الخطوة.

$$e_{ss} = \lim_{s \to 0} s\, R(s) [1 - T(s)]$$

$$= \lim_{s \to 0} s \frac{1}{s} \left[1 - \frac{10}{s^2+7s+10}\right]$$

$$= 1 - \frac{10}{0+0+10} = 0$$

R(s) → T(s) → C(s)

مستوصع

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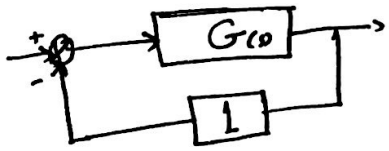
حساب الخطأ بدلالة دالة تحول المسار الأمامي $G(s)$.

$$e_{ss} = \lim \frac{s R(s)}{1 + G(s)}$$



* بشرط أن قيمة $H(s) = 1$ معدومة

مثال: أوجد قيمة الخطأ عند حالة الإستقرار اذا كانت دالة التحويل المسار الأمامي $G(s)$ معرفة بالعلاقة

$$G(s) = \frac{120(s+2)}{(s+3)(s+4)}$$

مع العلم ان اشارة الدخل هي: $r(t) = 5\,u(t)$

$$R(s) = 5/s$$

$$e_{ss} = \lim_{s \to 0} \frac{s\,R(s)}{1 + G(s)}$$

$$= \lim_{s \to 0} \frac{s \cdot 5/s}{1 + \frac{120(s+2)}{(s+3)(s+4)}} = \frac{5}{1 + \frac{120(0+2)}{(0+3)(0+4)}} = \frac{5}{1+20} = \frac{5}{21}$$

أوجد الخطأ في المثال السابق إذا كانت $r(t) = 5t\,u(t)$

$$R(s) = 5/s^2$$

$$e_{ss} = \frac{s * 5/s^2}{1 + \frac{120(s+2)}{(s+3)(s+4)}} = \frac{5}{s\left(1 + \frac{120(s+2)}{(s+3)(s+4)}\right)} = \frac{5}{0} = \infty$$

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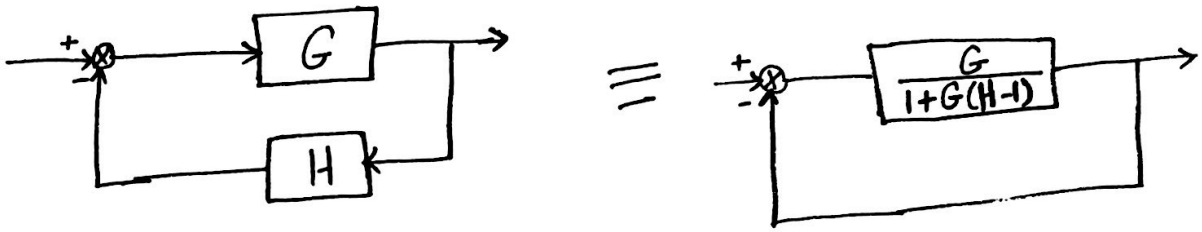
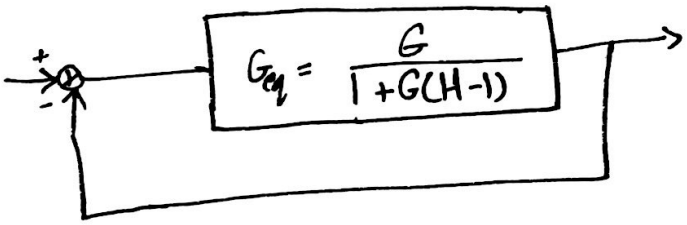
* حساب الخطأ عند $H(s) \neq 1$:

في هذه الحالة يتم تحويل النظام إلى نظام يكافئه ولكن بقيمة $H(s)=1$.
حيث تتم عملية التحويل كالآتي :





نستغل بـ G_{eq} في القوانين المعطاة سابقا.

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ثوابت الخطأ الإستاتيكي

1- ثابت الخطأ الإستاتيكي الموضعي (Position Error constant)

عندما تكون إشارة الدخل دالة الخطوة يُعرَّف الخطأ بثابت الخطأ الإستاتيكي الموضعي.

$$C_{ss} = \lim_{s\to 0} \frac{s\,R(s)}{1+G(s)} = \lim_{s\to 0} \frac{s * 1/s}{1+G(s)} = \frac{\lim_{s\to 0} 1}{\lim_{s\to 0} 1 + \lim_{s\to 0} G(s)}$$

$$C_{ss} = \frac{1}{1+\lim_{s\to 0} G(s)} = \frac{1}{1+K_p} \qquad \left(K_p = \lim_{s\to 0} G(s)\right)$$

2. ثابت الخطأ الإستاتيكي للسرعة $R(s) = 1/s^2$

$$C_{ss} = \lim_{s\to 0} \frac{s\,R(s)}{1+G(s)} = \lim_{s\to 0} \frac{s * 1/s^2}{1+G(s)} = \lim_{s\to 0} \frac{1}{s+sG(s)} = \frac{1}{0+\lim_{s\to 0} sG(s)}$$

$$C_{ss} = \frac{1}{K_v} \qquad \left(K_v = \lim_{s\to 0} s\,G(s)\right)$$

ثابت الخطأ الإستاتيكي للعجلة $R(s) = 1/s^3$

$$C_{ss} = \lim_{s\to 0} \frac{s\,R(s)}{1+G(s)} = \lim_{s\to 0} \frac{s\,\frac{1}{s^3}}{1+G(s)} = \lim_{s\to 0} \frac{1}{s^2+s^2G(s)}$$

$$C_{ss} = \frac{1}{\lim_{s\to 0} s^2 G(s)} = \frac{1}{K_a} \qquad \left(K_a = \lim_{s\to 0} s^2\,G(s)\right)$$

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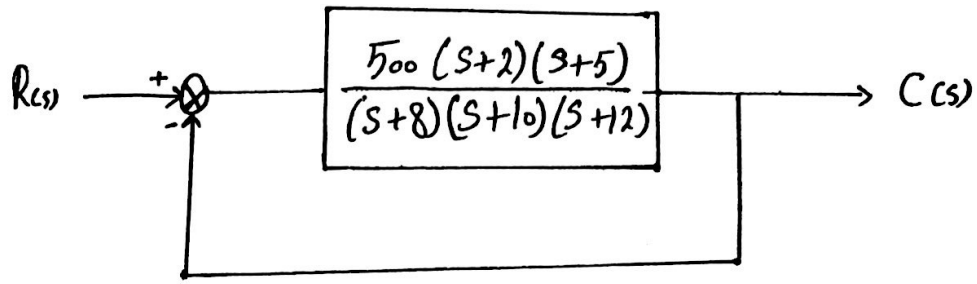
مثال : للمنظومة الموضحة بالشكل أوجد قيم K_a, K_v, K_p وقيمة الخطأ



$$K_p = \lim_{s\to 0} G(s) = \lim_{s\to 0} \frac{500(s+2)(s+5)}{(s+8)(s+10)(s+12)} = \frac{500(2)(5)}{(8)(10)(12)} = 5.208$$

$$e_{ss} = \frac{1}{1+K_p} = \frac{1}{1+5.208} = 0.16107$$

$$K_v = \lim_{s\to 0} sG(s) = \lim_{s\to 0} s\ \frac{500(s+2)(s+5)}{(s+8)(s+10)(s+12)} = 0$$

$$e_{ss} = \frac{1}{K_v} = \frac{1}{0} = \infty$$

$$K_a = \lim_{s\to 0} s^2 G(s) = \lim_{s\to 0} s^2\ \frac{500(s+2)(s+5)}{(s+8)(s+10)(s+12)} = 0$$

$$e_{ss} = \frac{1}{K_a} = \frac{1}{0} = \infty$$

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* جدول يلخص العلاقة بين الخطأ عند حالة الإستقرار واشارات الدخل ونوع نظام التحكم

Input	TYPE 0	type 1	type 2
step input $r(t) = u(t)$ $R(s) = 1/s$	K_p = constant $e_{ss} = \frac{1}{1+K_p}$	$K_p = \infty$ $e_{ss} = \frac{1}{1+K_p} = 0$	$K_p = \infty$ $e_{ss} = \frac{1}{1+K_p} = 0$
Ramp input $r(t) = t\,u(t)$ $R(s) = 1/s^2$	$K_v = 0$ $e_{ss} = \frac{1}{K_v} = \infty$	K_v = constant $e_{ss} = \frac{1}{K_v}$	$K_v = \infty$ $e_{ss} = \frac{1}{\infty} = 0$
Parabolic input $r(t) = t^2 u(t)$ $R(s) = 1/s^3$	$K_a = 0$ $e_{ss} = \frac{1}{K_a} = \infty$	$K_a = 0$ $e_{ss} = \frac{1}{K_a} = \infty$	K_a = constant $e_{ss} = \frac{1}{K_a}$

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مثال : ما هي المعلومات التي يمكن استخلاصها من المعلومة التالية

① $K_p = 1000$ ② $K_v = 1000$

$K_p = 1000$

ⓐ النظام من النوع ٠ Type 0

ⓑ إشارة الدخل هي دالة الخطوة : Step input

ⓒ

$$e_{ss} = \frac{1}{1+K_p} = \frac{1}{1001}$$

$K_v = 1000$

ⓐ النظام من النوع واحد Type one

ⓑ إشارة الدخل هي Ramp input

ⓒ

$$e_{ss} = \frac{1}{K_v} = \frac{1}{1000}$$

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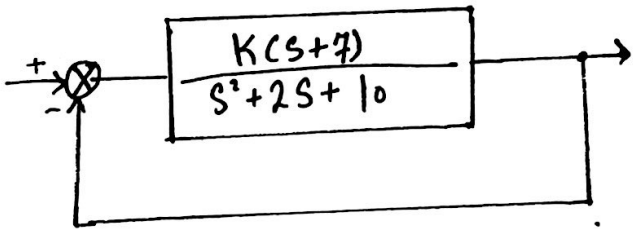
* حساسية الأنظمة (Sensitivity):

هي نسبة التغير الجزئي لدالة (Function) إلى نسبة التغير الجزئي لعنصر من عناصر الدالة عندما يقترب هذا التغير الجزئي للعنصر من الصفر.

$$S_p^F = \frac{\partial F}{\partial P} \frac{P}{F}$$

مثال: أوجد حساسية الخطأ عند حالة الإستقرار للتغير الذي يحدث للعنصر K للمنظومة التالية:



أولا نوجد دالة الخطأ (e_{ss}):

$$e_{ss} = \frac{1}{1+K_p} = \frac{1}{1+\lim_{s\to 0} G(s)} = \frac{1}{1+\frac{7K}{10}} = \frac{1}{\frac{10+7K}{10}} = \frac{10}{10+7K}$$

ثانيا نوجد حساسية (e_{ss}) للعنصر K

$$S_K^e = \frac{\partial e}{\partial K} \cdot \frac{K}{e} = \frac{(10+7K)0 - 10(7)}{(10+7K)^2} \frac{K}{e} = \frac{-70}{(10+7K)^2} \frac{K}{\frac{10}{(10+7K)}}$$

$$S_K^e = \frac{-70}{(10+7K)^2} * \frac{K(10+7K)}{10} = \frac{-70K}{10(10+7K)} = \frac{-7K}{10+7K}$$

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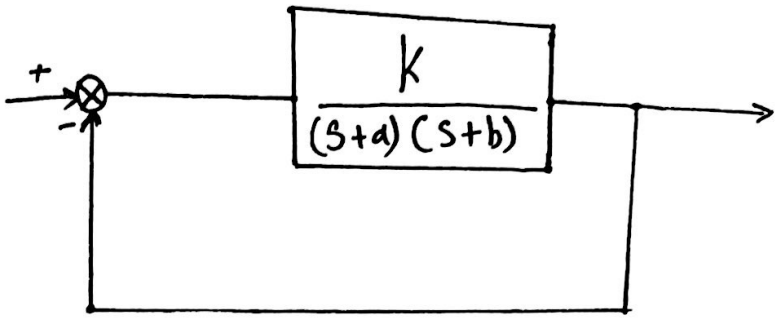
مثال: أوجد حساسية الخطأ عند حالة الإستقرار للتغيير الذي يحدث للعنصر K والعنصر a مع افتراض دالة الخطوة كمدخل.



أولا: نوجد e_{ss}

$$e_{ss} = \frac{1}{1+K_p} = \frac{1}{1+\lim_{s\to 0} G(s)} = \frac{1}{1+\frac{K}{ab}} = \frac{ab}{ab+K}$$

ثانيا: الحساسية بالنسبة للعنصر K:

$$S_K^e = \frac{2e}{2K} \cdot \frac{K}{e} = \frac{(ab+K)0 - ab(1)}{(ab+K)} * \frac{K}{\frac{ab}{(ab+K)}} = \frac{-Kab}{(ab+K)ab} = \frac{-K}{ab+K}$$

ثالثا: الحساسية بالنسبة للعنصر a:

$$S_a^e = \frac{2e}{2a} \cdot \frac{a}{e}$$

$$S_a^e = \frac{(ab+K)b - ab(b)}{(ab+K)^2} * \frac{a}{\frac{ab}{(ab+K)}} = \frac{ab+K-ab}{ab+K} = \frac{K}{ab+K}$$

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$$E(s) = R(s) - C_R(s) - C_D(s)$$

$$= R(s) - \frac{G_1(s)G_2(s)}{1+G_1(s)G_2(s)} R(s) - \frac{G_2(s)}{1+G_1(s)G_2(s)} D(s)$$

$$E(s) = \left[1 - \frac{G_1(s)G_2(s)}{1+G_1(s)G_2(s)}\right] R(s) - \left[\frac{G_2(s)}{1+G_1(s)G_2(s)}\right] D(s)$$

$$e(\infty) = \lim_{s \to 0} s\,E(s)$$

$$= \lim_{s \to 0} s \left\{ \left(1 - \frac{G_1G_2}{1+G_1G_2}\right) R(s) - \left(\frac{G_2}{1+G_1G_2}\right) D(s) \right\}$$

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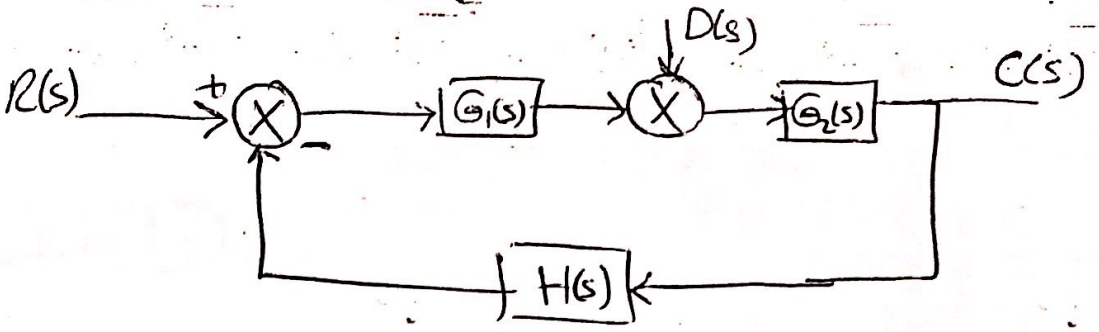
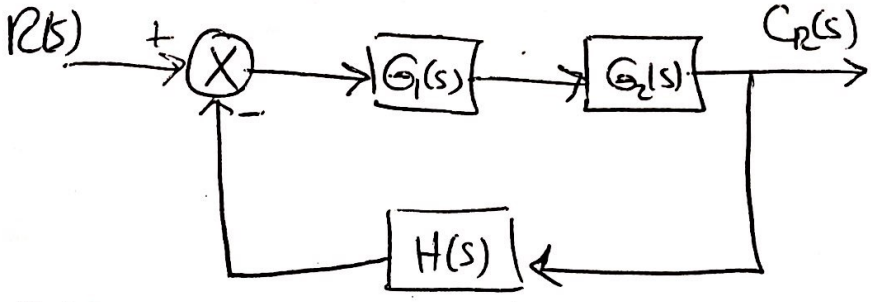
Steady state error for non-unity feedback system with disturbance



$$E(s) = R(s) - C(s)$$

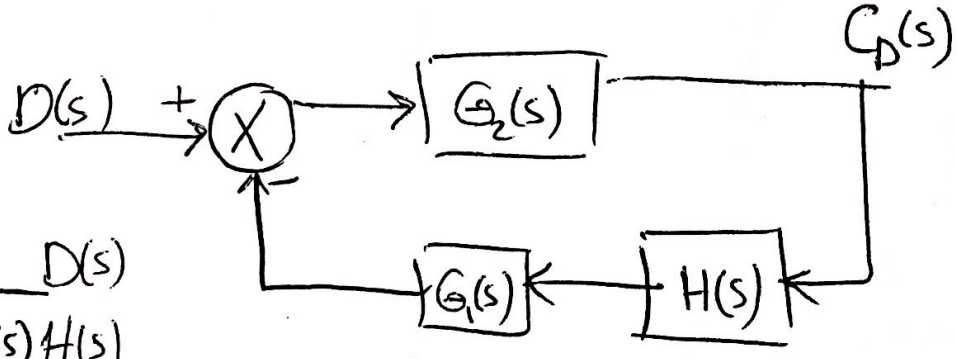
$$E(s) = R(s) - C(s)\Big|_{\text{due to } R(s),\ D(s)=0} - C(s)\Big|_{\text{due to } D(s),\ R(s)=0} \longrightarrow (1)$$

When $D(s) = 0$



$$C_R(s) = \frac{G_1(s)G_2(s)}{1 + G_1(s)G_2(s)H(s)} R(s)$$

When $R(s) = 0$



$$C_D(s) = \frac{G_2(s)}{1 + G_1(s)G_2(s)H(s)} D(s)$$

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$$C(s) = C_R(s) + C_D(s) \quad \cdots$$ [4] [3]

From [1]

$$E(s) = R(s) - C_R(s) - C_D(s)$$

$$E(s) = R(s) - \frac{G_1G_2}{1+G_1G_2H} R(s) - \frac{G_2}{1+G_1G_2H} D(s)$$

$$E(s) = \left[1 - \frac{G_1G_2}{1+G_1G_2H}\right] R(s) - \frac{G_2}{1+G_1G_2H} D(s) \rightarrow [2]$$

$$e(\infty) = \lim_{s \to 0} sE(s)$$

$$= \lim_{s \to 0} s\left\{\left(1 - \frac{G_1G_2}{1+G_1G_2H}\right) R(s) - \left(\frac{G_2}{1+G_1G_2H}\right) D(s)\right\}$$

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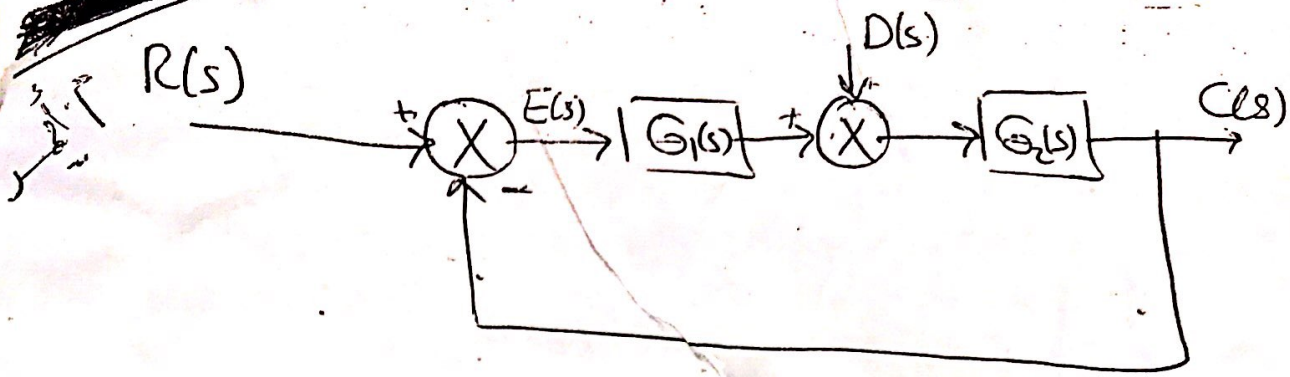
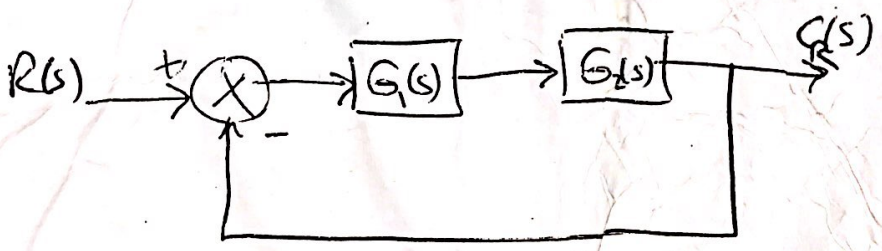
EE362 Steady state error for unity feedback system with disturbance



$$E(s) = R(s) - C(s)$$

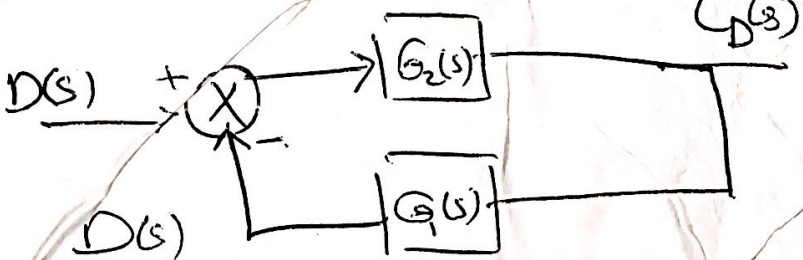
$$E(s) = R(s) - C(s)\Big|_{\text{due to } R(s),\ D(s)=0} - C(s)\Big|_{\text{due to } D(s),\ R(s)=0}$$

When $D(s) = 0$



$$C_R(s) = \frac{G_1(s)G_2(s)}{1 + G_1(s)G_2(s)} R(s)$$

When $R(s) = 0$



$$C_D(s) = \frac{G_2(s)}{1 + G_1(s)G_2(s)} D(s)$$

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EE 562

يوم الاربعاء 4/6/2014

م. أيمن

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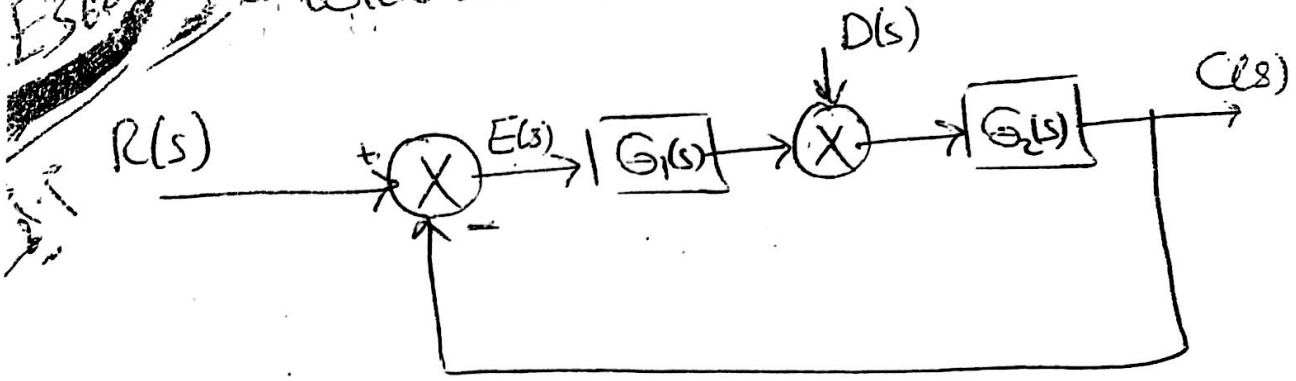
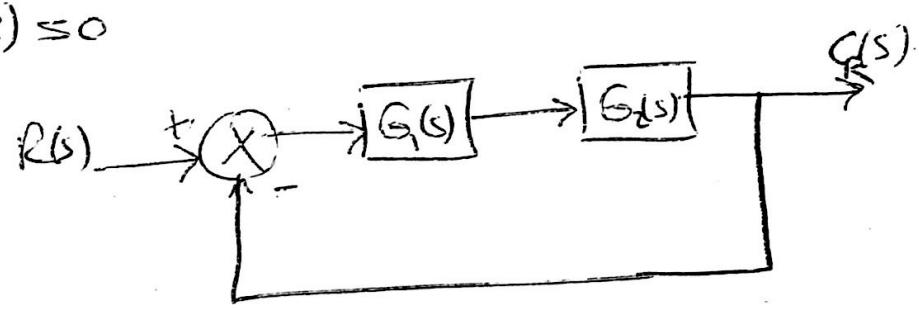
Eg: Steady state error for unity feedback sys with disturbance



$$E(s) = R(s) - C(s)$$

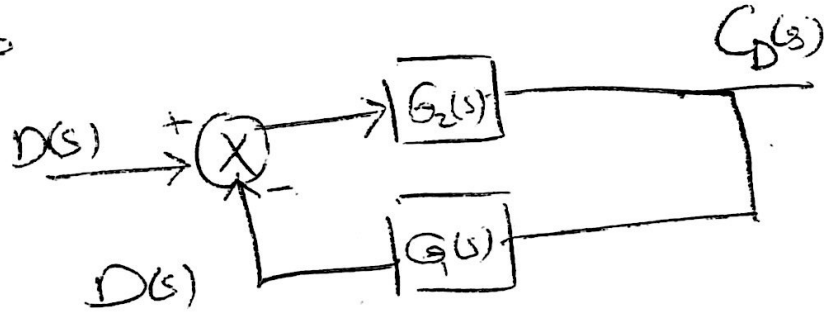
$$E(s) = R(s) - C(s)\Big|_{\substack{\text{due to } R(s) \\ D(s)=0}} - C(s)\Big|_{\substack{\text{due to } D(s) \\ R(s)=0}}$$

When $D(s) = 0$



$$C_R(s) = \frac{G_1(s)G_2(s)}{1 + G_1(s)G_2(s)} R(s)$$

When $R(s) = 0$



$$C_D(s) = \frac{G_2(s)}{1 + G_1(s)G_2(s)} D(s)$$

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$$= R(s) - C_R(s) - C_D(s)$$

$$= R(s) - \frac{G_1(s)G_2(s)}{1+G_1(s)G_2(s)} R(s) - \frac{G_2(s)}{1+G_1(s)G_2(s)} D(s)$$

$$E(s) = \left[1 - \frac{G_1(s)G_2(s)}{1+G_1(s)G_2(s)}\right] R(s) - \left[\frac{G_2(s)}{1+G_1(s)G_2(s)}\right] D(s)$$

$$e(\infty) = \lim_{s \to 0} s\,E(s)$$

$$= \lim_{s \to 0} s \left\{ \left(1 - \frac{G_1G_2}{1+G_1G_2}\right) R(s) - \left(\frac{G_2}{1+G_1G_2}\right) D(s) \right\}$$

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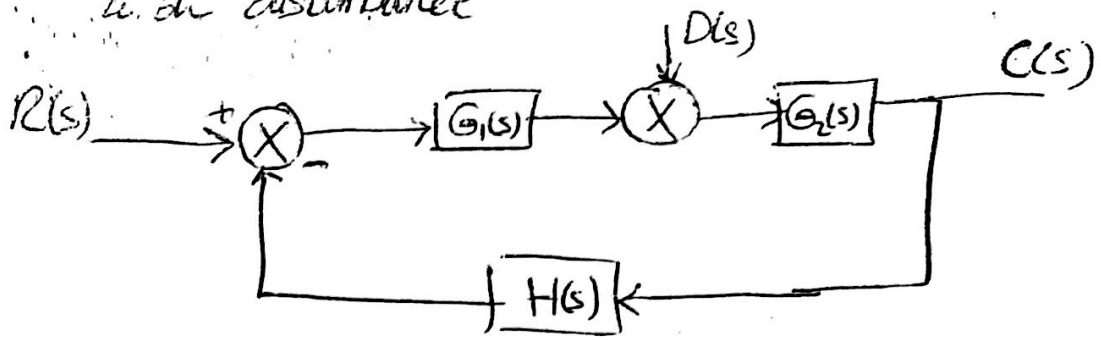
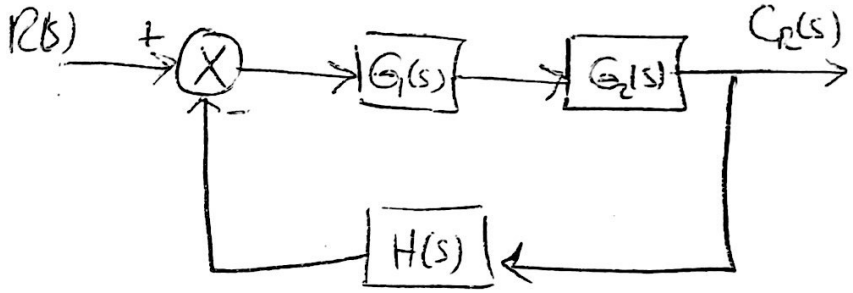
with disturbance



$$E(s) = R(s) - C(s)$$

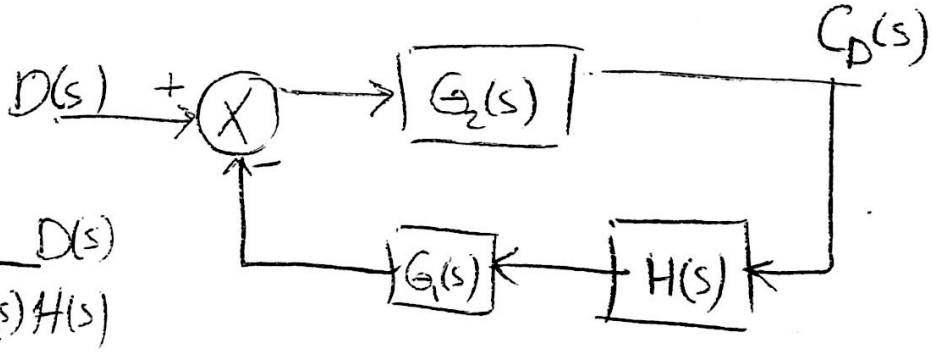
$$E(s) = R(s) - C(s)\Big|_{\text{due to } R(s),\ D(s)=0} - C(s)\Big|_{\text{due to } D(s),\ R(s)=0} \longrightarrow (1)$$

When $D(s) = 0$



$$C_R(s) = \frac{G_1(s)G_2(s)}{1 + G_1(s)G_2(s)H(s)} R(s)$$

When $R(s) = 0$



$$C_D(s) = \frac{G_2(s)}{1 + G_1(s)G_2(s)H(s)} D(s)$$

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$$C(s) = C_R(s) + C_D(s)$$

From [1]

$$E(s) = R(s) - C_R(s) - C_D(s)$$

$$E(s) = R(s) - \frac{G_1G_2}{1+G_1G_2H} R(s) - \frac{G_2}{1+G_1G_2H} D(s)$$

$$E(s) = \left[1 - \frac{G_1G_2}{1+G_1G_2H}\right] R(s) - \frac{G_2}{1+G_1G_2H} D(s) \rightarrow [2]$$

$$e(\infty) = \lim_{s \to 0} s\, E(s)$$

$$= \lim_{s \to 0} s \left\{ \left(1 - \frac{G_1G_2}{1+G_1G_2H}\right) R(s) - \left(\frac{G_2}{1+G_1G_2H}\right) D(s) \right\}$$

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EE 362 — [redacted] أ.د.

A unity feedback system has the following forward transfer function:

$$G(s) = \frac{10(s+20)(s+30)}{s(s+25)(s+35)}$$

Find the steady state error for the following inputs

1) $15u(t)$ 2) $15tu(t)$ 3) $15t^2u(t)$

For 1) [redacted] $e_{step}(\infty) = \lim_{s\to 0} s\frac{R(s)}{G(s)+1} = \lim_{s\to 0} \frac{s \not\propto \frac{15}{s}}{G(s)+1} \neq 0$

For 2) $e_{ramp}(\infty) = \lim_{s\to 0} \frac{s \not\propto \frac{15}{s^2}}{G(s)} = \lim_{s\to 0} \frac{15}{s \not\propto \frac{10(s+20)(s+30)}{s(s+25)(s+35)}} = 2.187$

For 3) $e_{parabolic}(\infty) = \lim_{s\to 0} \frac{s \not\propto \frac{15}{s^3}}{G(s)} = \lim_{s\to 0} \frac{15}{s^2 \not\propto \frac{10(s+20)(s+30)}{s(s+25)(s+35)}} = \infty$

Q) An input of $25t^3u(t)$ is applied to the input of a type 3 unity feedback system as shown where :-

$$G(s) = \frac{210(s+4)(s+6)(s+11)(s+13)}{s^3(s+7)(s+14)(s+19)}$$

(5)

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$$E(s) = \frac{R(s)}{1+G(s)} = \frac{150/s^4}{1 + \frac{210(s+4)(s+6)(s+11)(s+13)}{s^3(s+7)(s+14)(s+19)}}$$

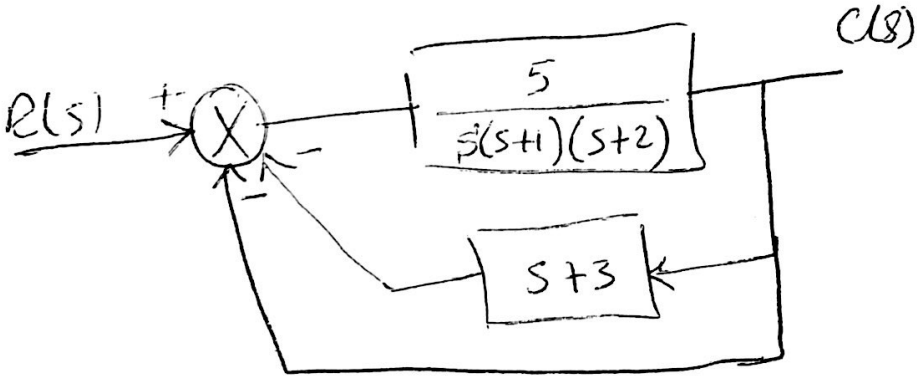
$$e(\infty) = \lim_{s\to 0} sE(s) = \frac{150}{\frac{210(4)(6)(11)(13)}{(7)(14)(19)}} = 0.387$$

Q For the system shown below

(a) Find K_p, K_v, and K_a

(b) Find the steady state error for an input of $50u(t)$, $50tu(t)$ and $50t^2u(t)$

(c) state the system type



$$G_2(s) = \frac{\frac{5}{s(s+1)(s+2)}}{1 + \frac{5(s+3)}{s(s+1)(s+2)}} = \frac{5}{s(s+1)(s+2)+5(s+3)} = \frac{5}{s^3+3s^2+7s+15}$$

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(a)

$$K_p = \lim_{s\to 0} G_e(s) = \frac{\frac{1}{5}}{1+\frac{1}{3}} = \frac{1}{3}$$

$$K_v = \lim_{s\to 0} sG_e(s) = 0$$

$$K_a = \lim_{s\to 0} s^2 G_e(s) = 0$$

(b) For $50u(t) \Rightarrow e(\infty) = \frac{50}{1+K_p} = 37.5$

For $50tu(t) \Rightarrow e(\infty) = \infty$

For $50t^2u(t) \Rightarrow e(\infty) = \infty$

(c) Type 0

Q Given the unity feedback system shown below

$$G(s) = \frac{100500(s+5)(s+14)(s+23)}{s(s+27)(s+\alpha)(s+33)}$$

Find the value of α to yield $K_v = 25000$

$$K_v = \lim_{s\to 0} sG(s) = \frac{100500(5)(14)(23)}{(27)(\alpha)(33)} = 25000$$

$$\boxed{\alpha = 7.26}$$

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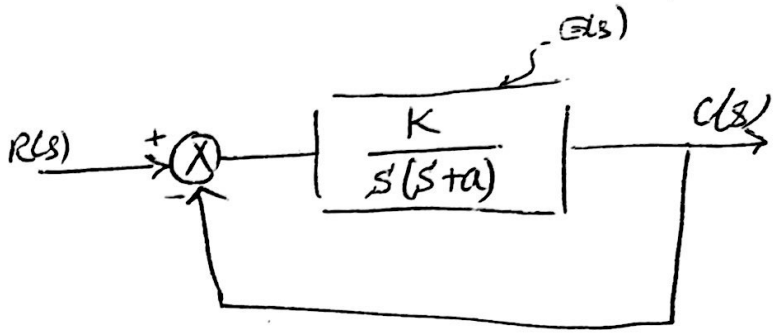
For the system shown below find the sensitivity of (steady state error) to changes in parameter "K" and parameter "a" with ~~ramp inputs~~



Solution :-

$$e(\infty) = \frac{1}{K_v} = \frac{a}{K} \quad \text{from} \quad K_v = \lim_{s \to 0} sG(s)$$

$$= \lim_{s \to 0} s \frac{K}{s(s+a)} = \frac{K}{a}$$

The sensitivity of $e(\infty)$ to changes in parameter "a" is

$$S_{e,a} = \frac{a}{e} \frac{\partial e}{\partial a} = \frac{a}{\frac{a}{K}} \left[\frac{1}{K} \right] = 1$$

The sensitivity of $e(\infty)$ to changes in parameter "K" is

$$S_{eK} = \frac{K}{e} \frac{\partial e}{\partial K} = \frac{K}{\frac{a}{K}} \left[\frac{-a}{K^2} \right] = -1$$

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Q For the unity feedback system, where

$$G(s) = \frac{K(s+13)(s+19)}{s(s+6)(s+9)(s+22)}$$

find the value of K to yield a steady state error of 0.4 for a ramp input of $2(t)$ u(t)

$$e_{ss} = \frac{2}{K_v} = 0.4$$

$$K_v = \lim_{s \to 0} sG(s) = \frac{K(13)(19)}{(6)(9)(22)}$$

$$0.4 = \frac{2}{\frac{K(13)(19)}{(6)(9)(22)}} \Longrightarrow \boxed{K = 325}$$

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